Technical Note

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Stream Ordering: A tool for Land Managers to Classify Western Oregon Streams

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Abstract

A 1:12,000 scale is suggested as optimal for fish and fish habitat analysis. The USGS 1:63,500 scale was found to be inconsistent in its stream ordering and delineation. Increasing width and depth and decreasing gradient with increasing stream order were observed. Fish diversity increased with increasing stream order, with cutthroat trout inhabiting all orders and chinook salmon inhabiting fourth and fifth order streams. Fourth order streams are the most important for coho salmon and steelhead trout. Stream ordering can be a more useful tool than other stream classification systems for fishery and habitat analysis in Northwestern Oregon.

Introduction

Stream channels are the result of interaction among precipitation, geomorphic features and vegetation. The existing drainage pattern is a result of interaction of these elements through time. Several methods have been used to catalogue the elements of a watershed. Stream ordering is one method that has been used extensively in North America (Kuehne 1962, Carter and Jones 1969, Platts 1979, Warren 1979, Vannote et al. 1980). The system developed by Horton (1945) and modified by Strahler (1957) is the most widely accepted. This system designates unbranched tributaries as first order streams, streams receiving two or more first order streams as second order streams, two or more second order streams as third order and so on.

Stream order has been used to classify and analyze habitat information in streams, and as a basis for classifying streams. Kuehne (1962) related stream order to physigraphic stream succession as indicated by fish distribution. Harrel, Davis and Doris (1967) found good correlation between stream order and species diversity (r= 0.96) and stream order and drainage area (r= 0.94). Platts (1974) related geomorphic conditions to stream classification. Whiteside and McNatt (1972) used physiochemical conditions together with stream order to determine relationships with fish species diversity.

The use of stream order for analyzing information or as a basis for stream classifications is influenced by the scale used in developing the ordering. For example, Hughes and Omernik (1981) found streams can be classified as a first to fourth order depending on the map scale. Differences in map scale makes it difficult to compare parameter ordering and stream classification systems reported in literature.

Differences in parameter distributions and stream classifications also result from the influence of different climatic and geomorphic influences. If applied to watersheds of different biogeoclimatical zones, stream order loses much of its value for data comparison (Warren 1979). The most valuable approach is the one used by Platts (1979) where physical and biological characteristics are analyzed by stream order for an area with uniform climatic and geomorphic patterns.

The purpose of this paper is twofold: To compare the classfication of stream order on maps of different scales; and to show relationships between physical characteristics, fish abundance and diversity and stream order.

Study Area Description

Physical and biological characteristics were collected over a three year period (1979-1981) from the Alsea

Illustration 1

Fourth order drainage in the Mollala watershed, showing steepness of first and second order tributaries.

and Nestucca River watersheds in the Coast Range and the Molalla and Santiam River watersheds of the Cascade Range on lands administered by the U.S. Bureau of Land Management (BLM) (Figure 1).

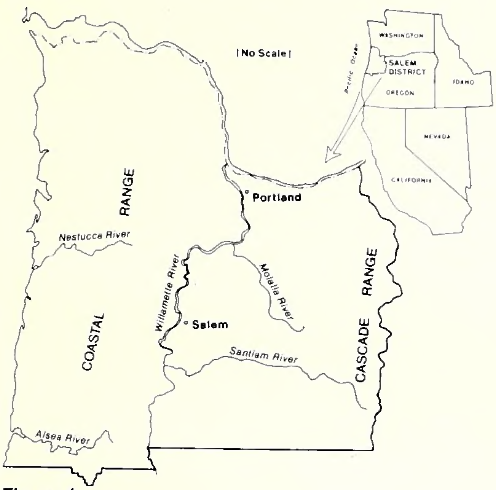


Figure 1

Geology of the coast range consists of rhythmically bedded sandstone and siltstone with inner bedded diorites and marine basalt and water laid taffaceous sediments. Cascade range geology comprises andesite, flow breccias and tuffs. Watersheds are primarily steep sloping where parent materials are resistant to weathering and moderately sloping on non-resistant parent material.

Soils for both ranges are mostly silty with top soils commonly gravely on steep slopes and clayey at lower elevations.

Elevation ranges from 150 to 3500 feet for coastal watersheds and 800 to 4200 feet for Cascade watersheds, with hillslopes averageing 33-34 percent (Bethlahmy 1972). Precipitation ranges from 80 to

Illustration 2

Drainage pattern in the coastal Nestucca watershed, which is generally a flatter topography than cascade drainages.

120 inches for coastal watersheds and 60 to 90 inches for Cascade watersheds.

The watersheds are forested primarily with Douglas-fir (*Pseudotsuga menziesii*). Other coniferous species include Western hemlock (*Tsuga heterophylla*) and Western red cedar (*Thuga plicata*).

Riparian overstory consists of mainly red alder (*Alnus rubra*) with some bigleaf maple (*Acer macrophyllium)* and Western red cedar *(Thuja plicata)*. Riparian understory vegetative types consist of vinemaple *(Acer circinatum)*, salmon-berry *(Rubus spectabilis)*, stinking current *(Ribes bacteosum)*, devils club *(Oplopanax horridum)*, sword fern *(Polystichum monitum)* and Western bracken fern *(Pteridium aquilinum)*.

Generally, over 50 percent of most watersheds inventoried have been logged, including riparian zones, and are in various stages of regeneration. The removal of old growth conifers along streams has dramatically reduced large instream woody structure, which in turn decreased pool quality and quantity and spawning gravels and increased cobble/rubble substrate.

Principal fish species include spring and fall chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), winter and summer steelhead trout (*Salmo gairdneri*), and sea-run and resident cutthroat trout (S. clarki). Other relatively abundant fishes include sculpin (*Cottus sp.*), dace (*Rhinichthys sp.*) and Pacific lamprey (*Lampetra tridentata*).

Methods

Streams that flow through BLM administered land were chosen for ordering and sampling physical variables and fish populations observation sampling. Stream ordering, watershed area and stream lengths were taken using a 1:12,000 scale map. Stream lengths were measured using a map wheel.

Physical habitat components were assessed during summer low flow conditions (June to September). Gradient was measured using a hand-held clinometer, all other physical variables were visually estimated as a percentage of the total stream reach inventoried.

Pools were defined as an area with little or no current and water deeper than stream portions with current. All other stream character types were designated riffle.

Bottom substrate was classified by size. Rocks greater than one foot in diameter were classified as boulders, six inches to one foot as cobble, three inches to six inches as rubble, 0.1 inches to three inches as gravel, and sand and silt as fines. Spawning gravel was visually estimated as a combined total for use by chinook, coho, steelhead and cutthroat.

Fish use was determined from Oregon Department of Fish and Wildlife and BLM visual observation inventories.

First order streams were not inventoried or sampled due to lack of identifiable channel, fish habitat and little or no surface water. Sixth order and larger streams were not inventoried due to the difficulty of inventorying larger rivers.

Results

Map Scale Analysis

To show problems in stream ordering using different scales, we compared a 1:12,000 scale to the widely available U.S. Geological Survey (USGS) 15-minute quadrangle 1:63,500 scale map (Table 1). Coastal watersheds follow a distinctive pattern of eliminating one stream order on the USGS map while the Cascade watersheds do not follow any obvious pattern.

Most first order and some second order streams on 1:12,000 maps do not appear on the USGS maps (Figure 2). On the 1:12,000 map scale, first and second order streams comprise around 79 percent of the total stream mileage for coastal and Cascade watersheds. The remaining stream miles are comprised of 12 percent third, seven percent fourth and two percent fifth order.

Table 1. Comparison of Map Scales Using Stream Order and Average Stream Mileage

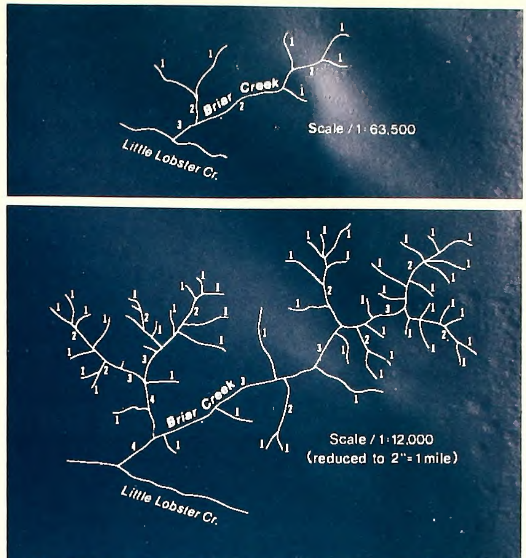
Coastal Watersheds[1]

		2nd Order		3rd Order		4th Order		5th Order	
		1:12000	1:63500	1:12000	1:63500	1:12000	1:63500	1:12000	1:63500
	1	.07	.04	2.7	1.0	8.4	3.3	24.3	7.8
Stream	2	0.5		1.2	0.3	3.9	1.5	9.1	2.1
Order	3			0.9		1.8	0.3	5.2	1.9
	4					2.0		2.9	0.2
	5							2.3	
Total		1.2	0.4	4.8	1.3	16.1	5.1	43.8	12.0

Cascade Watersheds[1]

		2nd Order		3rd Order		4th Order		5th Order	
		1:12000	1:63500	1:12000	1:63500	1:12000	1:63500	1:12000	1:63500
	1	.07	.03	2.8	1.5	11.1	3.9	28.4	5.0
Stream	2	0.7		1.5		5.1	1.2	11.5	0.7
Order	3			1.1		2.3	0.2	4.9	1.0
	4					1.9		2.7	
	5							2.4	
Total		1.4	0.3	5.4	1.5	20.4	5.3	49.9	6.7

[1] Ordered on 1:12,000 scale map



Briar Creek, coastal drainage, fourth order watershed (1:12,000)

Figure 2

Compared to the 1:12,000 scale, total mileage of a fifth order stream was reduced by 73 percent in coastal and 87 percent in Cascade watersheds on the USGS maps.

Stream Order Analysis

Watershed length, stream miles, area and stream denstiy for coastal and Cascade watersheds are shown in Table 2. Cascade watersheds are slightly larger in area but comparable to coastal watersheds in average stream mileage. Coastal watersheds show a higher average stream density (0.01 mi/acre) than Cascade watersheds (0.008 mi/acre), possibly due to their greater age and increased average annual rainfall.

Table 2. Stream Order Analysis

Coastal Watersheds[1]

No. of Order	Total Streams	Length (mi)	Avg. Length	Avg. Watershed Area (acres)	Density (mi/acre)
1	20	5.0	0.25	25	0.01
2	20	24.0	1.2	146	0.008
3	20	94.9	4.7	410	0.012
4	19	303.4	16.0	1,823	0.01
5	9	393.3	43.7	4,635	0.01

Cascade Watersheds[1]

No. of Order	Total Streams	Length (mi)	Avg. Length	Avg. Watershed Area (acres)	Density (mi/acre)
1	20	5.0	0.25	35	0.007
2	20	27.9	1.4	222	0.008
3	19	101.8	5.0	876	0.008
4	20	407.9	20.4	2,761	0.009
5	7	249.9	35.7	4,649	0.008

[1] Ordered on 1:12,000 scale

Physical Variable Analysis

Some relationships between physical variables and stream orders were expected, such as increasing width and depth with increasing stream order, due mainly to greater flows in larger order streams (Table 3). Greater stream area also provides increased fish habitat - larger pools, for example. Also expected was decreased gradient with increasing stream order.

Other relationships such as pool/riffle ratios, were not consistant with a change in stream order. Percentage of pool habitat increased with increasing stream order in coastal watersheds but varied in Cascade watersheds.

The greatest amount of spawning gravel occured in fourth order streams in coastal and fifth order in Cascade watersheds. This may be due to the lower gradient (four percent) of fourth order coastal streams compared to higher gradient (six percent) fourth order Cascade streams.

Table 3. Physical Variables in Relation to Stream Order

Coastal Watersheds

Physical Variable	Stream Order 2	3	4	5
Gradient (%)	18	6	4	3
Width (ft)	2	5	10	11
Depth (in)	8	16	16	33
Pool (%)	22	27	31	37
Riffle (%)	78	73	69	63
Sq. Yd. of Spawning Gravel/Mile	121	455	1,176	869
Bottom Substrate				
Bedrock	2	16	14	9
Boulder	11	15	15	14
Cobble	26	15	17	19
Rubble	9	10	15	11
Gravel	36	29	27	27
Fines	16	16	12	20

Cascade Watersheds

Physical Variable	Stream Order 2	3	4	5
Gradient (%)	11	9	6	3
Width (ft)	4	7	9	24
Depth (in)	2	4	8	12
Pool (%)	55	56	58	49
Riffle (%)	45	44	42	51
Sq. Yd. of Spawning Gravel/Mile	73	125	376	1,321
Bottom Substrate				
Bedrock	Information not available			
Boulder				
Cobble				
Rubble				
Gravel	13	16	18	20
Fines	3	4	5	3

Fish Distribution

Fish use all accessible streams where flow and suitable habitat are found (Table 4). First order streams have little, if any, value as fish habitat. Ephemeral stream flows and steep gradients limit fish use in first order streams.

Table 4. Percent Fish Use by Stream Order[1]

Coastal Watersheds

Order	Resident	Anadromous	Species[3]
1	—	—	—
2	39	—	CT
3	87	18	CT/ST/CO
4	98	63[2]	CT/ST/CO/CH
5	100	93[2]	CT/ST/CO/CH

Cascade Watersheds

Order	Resident	Anadromous	Species[3]
1	—	—	—
2	5	1	CT/ST/CO
3	37	6	CT/ST/CO
4	90	33[2]	CT/ST/CO/CH
5	100	65[2]	CT/ST/CO/CH

[1] Bureau of Land Management 1979, 1980
[2] Use restricted by blockage
[3] CT - Cutthroat, ST - Steelhead, CO - Coho, CH - Chinook

There is a noticeable difference between coastal and Cascade watersheds in fish use of second order streams. In coastal watersheds, around 39 percent of the second order streams contain resident cutthroat trout populations while only five percent of Cascade second order streams contain cutthroat populations. A few lower gradient larger second order Cascade streams support anadromous salmonids. Coastal and Cascade third order streams follow a similar pattern

Illustration 3

A second order stream flowing into a fifth order in the Nestucca watershed.

with salmonid use increasing to 87 percent in coastal and 37 percent in Cascade watersheds. Anadromous populations are found in 18 percent of coastal and six percent of Cascade third order streams. Although perennial in nature, most third order streams are too steep for returning adults and have inadequate flow to sustain juvenile anadromous populations.

Illustration 4

A typical third order stream, located in the Molalla watershed.

Most, if not all, fourth order streams support salmonid populations. Some streams above barriers once supported trout populations but these were lost as a result of habitat alteration. All fourth order coastal streams contain anadromous salmonid populations unless barriers prevent upstream movement. Some fourth order Cascade streams have

Illustration 5

A fourth order stream, supporting coho salmon and steelhead trout, located in the Nestucca watershed.

high gradient and low flows and are not capable of supporting anadromous salmonids. Gradients, flow and spawning gravels on most coastal fourth order streams are more suitable for coho and steelhead rather than chinook.

All fifth order streams support anadromous salmonids, unless barriers prevent upstream migration. Fifth order streams generally have the highest anadromous salmonid use due to greater habitat diversity and accessibility, with conditions suitable for all anadromous species.

Illustration 6
A fifth order stream, located in the Molalla watershed.

The only non-game fish found in third through fifth order streams were sculpins and Pacific lamprey. Other non-game fish, such as dace, inhabit sixth order and larger rivers.

The addition of species with increasing stream order has been observed by Kuehne (1962) and Platts (1979). This same trend was observed in both Cascade and coastal watersheds, with peak salmonid diversity found in fifth order streams.

Sixth order and larger rivers were not sampled or inventoried, however, they would primarily be used for migratory routes by all anadromous salmonids, spawning by chinook, and rearing by coho and steelhead.

Discussion

Similar map scales and detail must be used when employing stream ordering techniques. Map scale should be practical in size, generally available and of maximum detail. Following these criteria, a scale of 1:12,000 is suggested as optimal for fishery and habitat analysis in Northwestern Oregon. At this scale, first order streams can be easily defined and delineated.

Our map scale comparison substantiates McCoy's (1971) findings that the USGS "blueline method" of stream network delineation is the weakest and most inconsistant method of stream ordering.

Smaller stream orders consistantly showed steeper gradients and smaller size, in terms of width and depth, for both the coastal and Cascade watersheds.

The relative ages of the coast and Cascade ranges account for some of the differences in physical characteristics.The older coastal watersheds have formed more extensive drainage networks as shown by a higher stream density. These streams are of lower gradient and greater surface area than Cascade streams. The younger Cascade streams have less developed drainages and consequently have generally higher gradient with less surface area.

Pool/riffle ratios and bottom substrate are the result of numerous interactions in Cascade watersheds, where gradient is comparitively greater and winter freshets and runoff are generally more extreme, gravels are flushed out to progressively higher order, lower gradient streams. This scouring action tends to leave bedrock and large boulder substrate and consequently a relatively constant pool/riffle ratio (pools forming around boulders).

The Coastal watersheds retain more gravels due to lower gradients and more stable winter flow regimes. Also more common in the coastal watersheds are debris torrents and mass wasting. Debris torrents scour the channel eventually leaving substrate dominated by small boulder and cobble/rubble substrate. Accelerated mass wasting, common on unstable coastal parent material, accounts for a higher percentage of fines in these watersheds.

Many physical variables are effected by large instream woody structure, a component not quantified in this study. Woody structure can create pools, increase water depth, trap gravel and slow water velocities for streams in western Oregon (Swanson et al. 1976). Loss of stable woody structure in our study streams through timber removal has contributed to a change from the undisturbed to the current conditions, with reduced pool area, cover and other changes. We observed the value of woody material in creating and maintaining stream structure is greatest in the lower order streams.

Illustration 7
A stream logged and cleaned 20-30 years ago in the Alsea watershed, showing no woody instream structure.

Each stream order contributes either directly or indirectly to fish production. While most first and second order streams do not directly provide fish habitat, they comprise around 80 percent of the total stream miles in a watershed. Because of their influences on downstream temperature and sediment transport, first and second order streams are important in maintaining watershed stability and productivity. Alteration of these streams through vegetative removal and mechanical disturbance can seriously impact downstream habitat. Therefore, a given percentage of these streams should be left in an undisturbed condition. However, some low gradient second order Cascade streams entering directly into fourth order and larger streams support limited numbers of anadromous fish and should be fully protected.

Third order streams in both Cascade and coastal watersheds are used primarily by cutthroat with limited spawning and rearing use by steelhead and coho. Those third order streams that do support anadromous species usually have inadequate summer flows for juveniles which are displaced to larger streams in late spring or early summer.

Fourth order streams offer a wide range of habitats and thus support a high diversity. These streams appear to produce the most coho and steelhead, based on total stream miles, percent use and spawning gravel per mile. Fifth order streams have the highest species diversity and are important for chinook spawning and deeper water for rearing of yearling and older coho, steelhead and cutthroat.

Fish sampling in third through fifth order streams showed no correlations in juvenile fish density (q/m^2) between streams of the same order or with increasing stream order (unpublished data, Salem District, BLM). This was probably due to differences in habitat quality, caused mainly by past sluice-outs and elimination of riparian habitat and consequently large instream woody structure.

Stream ordering will provide a basis to compare streams for fishery managers, as well as other resource managers. Stream ordering can be used to gain generalized knowledge of a stream without expending time and effort at a specific site. Once the stream is ordered, probable species and physical characteristics can be predicted for a given area.

Many agencies employ a different classification system to identify important streams. These systems tend to be very subjective and and confusing when trying to determine a stream's overall value. We believe stream ordering is the best and most objective system for categorizing streams.

While stream ordering does not relate any specific instream habitat or riparian condition, it does lay the ground work for a common language for resource managers and planners. This language can then be used in reaching decisions on impacts to salmonids and salmonid habitat in Northwestern Oregon.

Additional studies, covering a wider area, will provide data to assist in characterizing habitat and stream order relationships and may provide a procedure for more effective management of aquatic resources.

Literature Cited

Bureau of Land Management. 1979. Unit Resource Analysis, Westside Salem. Salem District Office, Salem, Oregon, USA.

Bureau of Land Management. 1980. Unit Resource Analysis, Eastside Salem. Salem District Office, Salem, Oregon, USA.

Carter, J.P. and A.R. Jones. 1969. Inventory and classification of streams in the Upper Cumberland River drainage of Kentucky. Department of Fish and Wildlife Resources, Kentucky Fisheries Bulletin No. 52.

Harrel, R.C., B.J. Davis and T.C. Doris. 1967. Stream order and species diversity of fishes in an intermittent stream. American Naturalist 78:428-436.

Horton, R.E. 1945. Erosional development of streams and their drainages. Geological Society of American Bulletin 56:275-370.

Hughes, R.M. and J.M. Omernik. 1981. Use and misuse of the terms watershed and stream order. Pages 320-326. L.A. Krumholz, editor. Procedings of a symposium on warmwater fishes, Knoxville, Tennessee, USA.

Kuehne, R.A. 1962. A classification of streams illustrated by fish distribution in an Eastern Kentucky creek. Ecology 43:608-614.

McCoy, R.M. 1971. Rapid measurement of drainage density. Geological Society of America 82:757-762.

Platts, W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem management. USDA Forest Service, SEAM Program, Billings, Montana, USA.

Platts, W.S. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho River drainage. Fisheries 4(2):5-9.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913-920.

Swanson, F.J., G.W. Lienkaemper and J.R. Sedell. 1976. History, physical effects and management implications of large organic debris in western Oregon streams. USDA Forest Service General Technical Report PNW-56.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Warren, C.E. 1979. Toward classification and rationale for watershed management and stream protection. EPA-600/3-79-059. Environmental Research Laboratory. U.S. Environmental Protection Agency, Corvallis, Oregon, USA.

Whiteside, B.G. and R.M. McNatt. 1972. Fish species in relation to stream order and physiochemical conditions in the Plum Creek drainage basin. American Midland Naturalist 88:90-100.

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